Science Standards of Learning

Teacher Resource Guide

Chemistry

Commonwealth of Virginia
Department of Education
Richmond, Virginia
2000

Standard CH.1 a, b, c

The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated, produce observations and verifiable data. Key concepts include

- designated laboratory techniques;
- safe use of chemicals and equipment; and
- proper response to emergency situations.

Essential Understandings	Essential Knowledge and Skills
· Measurements of quantity include length, volume, mass, temperature, time, and pressure to the correct number of significant digits. · Techniques for experimentation involve the identification and the proper use of chemicals, the description of equipment, and the recommended statewide framework for high school laboratory safety. · Measurements are useful in gathering data about chemicals and how they behave.	<u>Skills</u> · Make the following measurements using the specified equipment: − Volume: graduated cylinder, pipette, volumetric flask, buret − Mass: electronic or dial-a-gram − Temperature: thermometer and/or temperature probe − Pressure: barometer and/or pressure probe. · Identify, locate, and know how to use laboratory safety equipment including aprons, goggles, gloves, fire extinguishers, fire blanket, safety shower, eye wash, broken glass container, and fume hood. · Demonstrate the following basic lab techniques: filtering, decanting, using chromatography, lighting gas burners.

Standard CH.1 a, b, c (continued)

Essential Understandings	Essential Knowledge and Skills
	· Identify the following basic lab equipment: beaker, flask, graduated cylinder, test tube, test tube rack, test tube holder, ring stand, wire gauze, clay triangle, crucible with lid, evaporation dish, watch glass, wash bottle, and dropping pipette. · Understand and demonstrate: − Material Safety Data Sheet (MSDS) warnings, including handling chemicals, lethal dose (LD), hazards, disposal, chemical spill clean-up − safety rules for a science − laboratory safety cautions − safe techniques and procedures.

Standard CH.1 d, e

The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated, produce observations and verifiable data. Key concepts include

- multiple variables are manipulated with repeated trials; and
- accurate recording, organizing, and analysis of data through repeated trials.

Essential Understandings	Essential Knowledge and Skills
· Repeated trials during experimentation ensure verifiable data. · Data tables are used to record and organize measurements.	Skills · Identify variables. · Predict outcome(s) when a variable is changed. · Design and perform experiments to test predictions. · Demonstrate precision (reproducibility) in measurement. · Understand accuracy in terms of closeness to the true value of a measure.

Standard CH.1 f, g

The student will investigate and understand that experiments in which variables are measured, analyzed, and evaluated, produce observations and verifiable data. Key concepts include

- mathematical and procedural error analysis; and
- mathematical manipulations (SI units, scientific notation, linear equations, graphing, ratio and proportion, significant digits, dimensional analysis, use of scientific calculator).

Essential Understandings	Essential Knowledge and Skills
· Measurements must be expressed in SI units. · Scientific notation is used to write very small and very large numbers. · Algebraic equations represent relationships between dependent and independent variables. · Graphed data give a picture of a relationship. · Ratios and proportions are used in calculations. · Significant digits of a measurement are the number of known digits together with one estimated digit. · The last digit of any valid measurement must be estimated and is therefore uncertain.	<u>Skills</u> · Discover and eliminate procedural errors. · Know most frequently used SI prefixes and their values (milli-, centi-, deci-, kilo-). · Demonstrate the use of scientific notation, using the correct number of significant digits with powers of ten notation for the decimal place. · Correctly utilize the following when graphing data: – dependent variable (vertical axis) – independent variable (horizontal axis) – scale and units of a graph – regression line (best fit curve). · Calculate mole ratios, percent composition, conversions, dimensional analysis, and relative atomic mass.

Standard CH.1 f, g (continued)

Essential Understandings	Essential Knowledge and Skills
· Dimensional analysis is a way of translating a measurement from one unit to another unit. · Scientific calculators can be used to manage the mathematics of chemistry. · Mathematical procedures are used to validate data.	· Use the rules for performing operations with significant digits. · Correctly use scientific calculators. · Use temperature and/or pH probes to gather data. · Read a measurement from a graduated scale stating measured digits plus the estimated digit. · Use data collected to calculate percent error. · Determine the mean of a set of measurements.

Standard CH.2 a, b, c

The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of

- mass/atomic number;
- isotopes/half-lives/nuclear particles; and
- particle/mass charge.

Essential Understandings	Essential Knowledge and Skills
· The periodic table is arranged by increasing atomic numbers. · The atomic number of an element is the same as the number of protons. · In a neutral atom, the number of electrons is the same as the number of protons. · All atoms of the same element have the same number of protons. · The atomic mass for each element is the weighted average of that element's naturally occurring isotopes.	<u>Knowledge</u> · Electrons have little mass and a negative ("-") charge. They are located in electron clouds or probability clouds outside the nucleus. · Protons have a positive ("+") charge. Neutrons have no charge. Protons and neutrons are located in the nucleus of the atom and comprise most it's mass. · An isotope is an atom that has the same number of protons as another atom, but has a different number of neutrons. Some isotopes are radioactive; many are not. · Half-life is the length of time required for half of a given sample of a radioactive isotope to decay. <u>Skills</u> Determine, using a periodic chart, the atomic number, atomic mass, the number of protons, the number of electrons, and the number of neutrons of any neutral atom of a particular element.

Standard CH.2 d, e, f

The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of

- families/groups;
- series/periods; and
- trends/patterns: atomic/nuclear radii, electronegativity, shielding effect.

Essential Understandings	Essential Knowledge and Skills
· Periodicity is regularly repeating patterns or trends in the chemical and physical properties of the elements arranged in the periodic table. · Vertical columns called groups have similar properties because of their similar valence electron configurations. · Horizontal rows called periods have predictable properties based on an increasing number of electrons in the outer orbitals.	<u>Knowledge</u> · The Periodic Law states that when elements are arranged in order of increasing atomic number, their physical and chemical properties show a periodic pattern. · The names of groups and periods on the periodic chart are alkali metals, alkaline earth metals, transition metals, halogens, inert gases, and metalloids. · Periods and groups are named by numbering columns and rows. · Some elements (oxygen, hydrogen, and nitrogen) naturally occur as diatomic molecules. · Electronegativity increases from left to right, and decreases from top to bottom.

Standard CH.2 d, e, f (continued)

Essential Understandings	Essential Knowledge and Skills
	· Shielding effect is constant across the period and increases within given groups from top to bottom. · Atomic radius decreases from left to right and increases from top to bottom within given groups. · Ionization energies generally increase from left to right and decrease from top to bottom of a given group. <u>Skills</u> Determine the Electron Configuration for elements up to Z=17.

Standard CH.2 g

The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of

- electron configurations/oxidation numbers.

Essential Understandings	Essential Knowledge and Skills
· Electron configuration is the arrangement of electrons around the nucleus of an atom based on their energy level. · Atoms can gain or lose electrons within the outer energy level.	<u>Knowledge</u> · Electrons are added one at a time to the lowest energy level (Aufbau Principle). · An orbital can hold a maximum of two electrons (Pauli Exclusion Principle). · Electrons occupy equal-energy orbitals so that a maximum number of unpaired electrons results. (Hund's Rule). · Energy levels are designated 1 – 7. Orbitals are designated s, p, d, and f according to their shapes. (s, p, d, f orbitals relate to the regions of the Periodic Table.) · Loss of electrons from neutral atoms results in the formation of an ion with a positive charge (cation). · Gain of electrons by a neutral atom results in the formation of an ion with a negative charge (anion). · Transition metals can have multiple oxidation states.

Standard CH.2 h

The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of

- chemical/physical properties.

Essential Understandings	Essential Knowledge and Skills
· Matter is classified by its chemical and physical properties. · Physical properties refer to the condition or quality of a substance that can be observed or measured without changing the substance's composition. · Chemical properties refer to the ability of a substance to undergo chemical reaction and to form a new substance.	<u>Knowledge</u> · Matter occurs as element (pure), compounds (pure), and mixtures which may be homogeneous (solutions) or heterogeneous. · Important physical properties are density, conductivity, melting point, boiling point, malleability, and ductility. · Reactivity is the tendency of an element to enter into a chemical reaction.

Standard CH.2 i

The student will investigate and understand that the placement of elements on the periodic table is a function of their atomic structure. The periodic table is a tool used for the investigations of

- historical/quantum models.

Essential Understandings	Essential Knowledge and Skills
· Discoveries and insights related to its structure have changed the model of the atom over time. · The modern atomic theory is called the Quantum Mechanical Model.	<u>Knowledge</u> Major insights regarding the atomic model of the atom and principal scientists include − particles – Democritus − first atomic theory of matter – John Dalton − discovery of the electron – J. J. Thompson − discovery of the nucleus – Rutherford − discovery of charge of electron – Millikan − planetary model of atom – Neils Bohr − periodic table – Mendeleev − quantum of energy – Planck − uncertainty principle – Heisenberg − wave theory – de Broglie.

Standard CH.3 a, b, c, d

The student will investigate and understand how conservation of energy and matter is expressed in chemical formulas and balanced equations. Key concepts include

- nomenclature;
- balancing chemical equations;
- writing chemical formulas—molecular, structural, empirical, and Lewis diagrams; and
- bonding types—ionic, covalent.

Essential Understandings	Essential Knowledge and Skills
· IUPAC system is used for naming compounds. · Conservation of matter is represented in balanced chemical equations. · Chemical formulas are used to represent compounds. · Subscripts represent the relative number of each type of atom in a molecule or formula unit. · A coefficient is a quantity that precedes a reactant or product symbol or formula in a chemical equation and indicates the relative number of particles involved in the reaction. · Bonds form between atoms to achieve stability.	<u>Knowledge</u> · When pairs of elements form two or more compounds, the masses of one element that combine with a fixed mass of the other element form simple, whole-number ratios (Law of Multiple Proportions). · The empirical formula shows the simplest whole-number ratio in which the atoms of the elements are present in the compound. · The molecular formula shows the actual number of atoms of each element in one molecule of the substance. · Structural formulas also show the arrangements of atoms and bonds. · Covalent bonds involve the sharing of electrons.

Standard CH.3 a, b, c, d (continued)

Essential Understandings	Essential Knowledge and Skills
	· Ionic bonds involve the transfer of electrons. · Ionization energy is the energy required to remove the most loosely held electron from a neutral atom. Elements with low ionization energy form ions easily. · Electronegativity is the measure of the attraction of an atom for electrons in a covalent bond. · Polar molecules result when a molecule behaves as if one end were positive and the other end negative. <u>Skills</u> · Name binary compounds using the Stock system (Roman numerals). · Predict, draw, and name molecular shapes (linear, bent, trigonal planar, tetrahedral). · Write equations, determine formulas, and balance chemical equations. · Know the chemical formulas for certain common substances (water, carbon monoxide, carbon dioxide, sulfur dioxide, and carbon tetraflouride). · Draw Lewis Dot Diagrams to show covalent bonding.

Standard CH.3 e, f, g

The student will investigate and understand how conservation of energy and matter is expressed in chemical formulas and balanced equations. Key concepts include

- reaction types—synthesis, decomposition, single and double replacement, oxidation-reduction, neutralization, nuclear, exothermic and endothermic, spontaneous/non-spontaneous, dissociation ionization;
- physical and chemical equilibrium; and
- reaction rates and kinetics: activation energy, catalysis, degree of randomness.

Essential Understandings	Essential Knowledge and Skills
· Elements and compounds react in different ways. · Spontaneous reactions may be fast or slow. · Randomness (entropy), heat content (enthalpy), and temperature affect spontaneity. · A reaction is said to reach equilibrium when the forward reaction rate equals the reverse reaction rate. · Reaction rates/kinetics are affected by activation energy, catalysis, and the degree of randomness (entropy).	<u>Knowledge</u> · Major types of chemical reactions are − synthesis **(A+B → AB)** − decomposition **(BC → B+C)** − single replacement **(A+BC → B+AC)** − double replacement **(AC+BD → AD+BC).** · Chemical reactions based on the net heat energy are exothermic reaction (heat producing) and endothermic reaction (heat absorbing). · Reactions can occur in two directions simultaneously. · Le Chatelier's Principle indicates the qualitative prediction of direction of change with temperature, pressure, and concentration.

Standard CH.3 e, f, g (continued)

Essential Understandings	Essential Knowledge and Skills
	· Catalysts decrease the amount of activation energy needed. <u>Skills</u> Recognize equations for redox reactions, neutralization reactions, and nuclear reactions.

Standard CH.4 a, b

The student will investigate and understand that quantities in a chemical reaction are based on molar relationships. Key concepts include

- Avogadro's principle, molar volume; and
- stoichiometric relationships.

Essential Understandings	Essential Knowledge and Skills
· Atoms and molecules are too small to count by usual means. · A mole is a way of counting any type of particle (atoms, molecules, and formula units). · Stoichiometry involves quantitative relationships. · Stoichiometric relationships are based on mole quantities in a balanced equation.	<u>Knowledge</u> · Avogadro's number = 6.02×10^{23} particles per mole. · Molar volume = 22.4 dm^3/mole and/or 22.4 L/mole for any gas at STP. · Total grams of reactant(s) = total grams of product(s). <u>Skills</u> · Make calculations involving the following relationships − mole-mole − mass-mass − mole-mass − mass-volume − mole-volume − volume-volume − particle-particle. · Identify the limiting reactant (reagent) in a reaction. · Calculate percent yield of a reaction.

Standard CH.4 c, d, e, f

The student will investigate and understand that quantities in a chemical reaction are based on molar relationships. Key concepts include

- partial pressure;
- gas laws;
- solution concentrations; and
- chemical equilibrium.

Essential Understandings	Essential Knowledge and Skills
· Gases have mass and occupy space. · Gas particles are in constant, rapid, random motion and exert pressure as they collide with the walls of their containers. · Gas particles are separated from each other by relatively large distances. · An Ideal Gas does not exist, but this concept is used to model gas behavior. · A Real Gas exists, has intermolecular forces and particle volume, and can change states. · Equal volumes of gases at the same temperature and pressure contain an equal number of particles.	<u>Knowledge</u> · The pressure and volume of a sample of a gas at constant temperature are inversely proportional to each other (Bolye's Law). · At constant pressure, the volume of a fixed amount of gas is directly proportional to its absolute temperature (Charles' Law). · The sum of the partial pressures of all the components in a gas mixture is equal to the total pressure of a gas mixture (Dalton's Law of Partial Pressure). · Ideal Gas Law states that PV = nRT. · Molarity = moles/dm^3 and/or moles/L of solution. · Solvents can be solids, liquids, or gases.

Standard CH.4 c, d, e, f (continued)

Essential Understandings	Essential Knowledge and Skills
· A solution is a solute dissolved in a solvent. · Concentration is the amount of solute in moles divided by the number of liters of solution.	· Pressure Units include K Pa and mm of Hg. <u>Skills</u> Solve problems and interpret graphs involving all gas laws.

Standard CH.4 g

The student will investigate and understand that quantities in a chemical reaction are based on molar relationships. Key concepts include

- acid/base theory: strong/weak electrolytes, dissociation/ionization (pH, pOH), and titration.

Essential Understandings	Essential Knowledge and Skills
· Two important classes of compounds are acids and bases. · Acids and bases are defined by several theories. · Acids and bases dissociate in varying degrees.	<u>Knowledge</u> · Arrhenius acids are characterized by their sour taste, low pH, and the fact that they turn litmus paper red. Arrhenius bases are characterized by their bitter taste, slippery feel, high pH, and the fact that they turn litmus paper blue. · Bronsted-Lowry-acids are proton donors; whereas, bases are proton acceptors. · $2H_2O_{(l)} <-> H_3O^+ + OH^-$ · pH is the number that denotes hydrogen (hydronium) ion concentration. · pOH is the number that denotes hydroxide ion concentration. · pH + pOH = 14

Standard CH.4 g (continued)

Essential Understandings	Essential Knowledge and Skills
	· Strong acid-strong base titration is the process that measures [H+] and [OH-]. · Indicators show color changes at certain pHs. · Strong electrolytes dissociate completely. · Weak electrolytes dissociate partially.

Standard CH.5 a, b, c

The student will investigate and understand that the phases of matter are explained by kinetic theory and forces of attraction between particles. Key concepts include

- pressure, temperature, and volume;
- vapor pressure; and
- partial pressures.

Essential Understandings	Essential Knowledge and Skills
· Atoms and molecules are in constant motion. · The Kinetic Molecular Theory is a model for predicting and explaining gas behavior. · Forces of attraction between molecules determine the physical changes of state. · Vapor pressure is a property of a substance determined by intermolecular forces.	<u>Knowledge</u> · Pressure, temperature, and volume changes can cause a change in physical state. · Forces of attraction include hydrogen bonding, dipole-dipole attraction, and van der Waals forces.

Standard CH.5 d, e, f, g, h

The student will investigate and understand that the phases of matter are explained by kinetic theory and forces of attraction between particles. Key concepts include

- phase changes;
- molar heats of fusion and vaporization;
- specific heat capacity;
- solutions; and
- colligative properties.

Essential Understandings	Essential Knowledge and Skills
· Solid, liquid, and gas phases of a substance have different energy content. · Specific amounts of energy are absorbed or released during phase changes. · Specific heat capacity is a property of a substance. · Solutions can exist in any state or combination of states. · Polar substances dissolve ionic or polar substances; nonpolar substances dissolve nonpolar substances. · The number of solute particles changes the freezing point and boiling point of a pure substance.	<u>Knowledge</u> · Solutions can be solute/solvent, gas/gas, gas/liquid, liquid/liquid, solid/liquid, gas/solid, liquid/solid, and solid/solid. · Boiling point of liquids is affected by changes in atmospheric pressure. · Freezing point of liquids is affected by the presence of certain solutes. <u>Skills</u> · Graph and interpret a heating curve (temperature vs. time). · Calculate energy changes using specific heat capacity.

Standard CH.5 d, e, f, g, h (continued)

Essential Understandings	Essential Knowledge and Skills
	· Calculate energy changes using molar heat of fusion and molar heat of vaporization. · Interpret a phase diagram of water. · Perform calorimetry calculations. · Recognize polar molecules and non-polar molecules.

Standard CH.6 a, b, c

The student will investigate and understand how basic chemical principles relate to other areas of chemistry. Key concepts include

- organic and biochemistry*;
- nuclear chemistry; and
- environmental chemistry.

*The topics of organic and biochemistry may appear in content in other questions, but will not be tested or reported separately.

Essential Understandings	Essential Knowledge and Skills
· Organic chemistry is the study of compounds containing carbon. · Carbon atoms can form bonds with other carbon atoms. · Molecules of alkanes, alkenes, and alkynes are named using a prefix to describe the length of the carbon chain. · Biochemistry is the study of chemistry that occurs in living organisms. · Nuclear chemistry is a study of changes in the composition of the nucleus of an atom.	<u>Knowledge</u> · Alkanes have single bonds and are saturated hydrocarbons; alkenes have a double bond(s) and are unsaturated; alkynes have a triple bond(s) and are unsaturated. · Functional groups determine the properties of carbon compounds. · The beneficial uses of radioisotopes include medical diagnosis and treatment and dating ancient materials. <u>Skills</u> · Determine the half-life of a radioactive substance. · Describe alpha, beta, and gamma radiation with respect to penetrating power and composition.

Standard CH.6 a, b, c (continued)

Essential Understandings	Essential Knowledge and Skills
· Environmental chemistry is a study of chemical changes that affect the atmosphere, water, and surface of the earth.	· Define fusion and fission. · Delineate causes and environmental issues surrounding – nuclear waste disposal – radon – acid rain – ozone depletion – global warming.